

N65-24657
(ACCESSION NUMBER)
17
(PAGES)
(NASA CR OR TMX OR AD NUMBER)

(THRU)
1
(CODE)
13
(CATEGORY)

NASA TT F-8284

GPO PRICE \$ _____

OTS PRICE(S) \$ _____

Hard copy (HC) 1.00Microfiche (MF) .50

GRAVITATIONAL SEPARATION, COMPOSITION AND STRUCTURAL
PARAMETERS OF THE NIGHT ATMOSPHERE IN
THE 100 — 210 KM ALTITUDE RANGE

by

A. A. Pokhunkov

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON

OCTOBER 1962

OCT 8 1962

GRAVITATIONAL SEPARATION, COMPOSITION AND STRUCTURAL
PARAMETERS OF THE NIGHT ATMOSPHERE IN
THE 100-210 KM ALTITUDE RANGE *

Sb."ISZ" (AES), vyp.13,
pp.110 - 118,
Izd-vo A.N.SSSR, 1962.

by A. A. Pokhunkov

24657

ARST

10495

Measurements of the composition of the upper atmosphere (nonionized gases) have been carried out by a 5-cascade radio-frequency mass-spectrometer installed, as in earlier experiments [1, 2], in a retrievable geophysical container separating from the rocket. The launching was carried out on 23 September 1960 at 0056 hours local time at middle latitudes of the European SSSR. The raising of the container was made with the aid of a large geophysical rocket vertically to the altitude of 210 km. Measurements of the composition were made after container's separation, at distances from the rocket in the range of several tens to several hundred meters.

An improved variant of radiofrequency mass-spectrometer was used in this experiment in comparison with that used in the 1959 experiments [1, 2]. Its description has been published in [3]. The general view of the device, the block diagram of its installation in the container and its technical characteristics are brought out in [4].

Respectively 51 and 50 mass spectra of atmospheric gases have been obtained at ascent and descent in the 100 - 210 km range.

* Gravitatsionnoye razdeleniye, sostav i strukturnyye parametry nochnoy atmosfery na vysotakh ot 100 do 210 km.

The mass spectrum recordings were conducted by means of a galvanometer oscillograph installed in a hermetically-sealed compartment of the container. At such registration the minimum registrable ion current of the analyzer's collector constituted $4 \cdot 10^{-14}$ a (for an input resistance $R = 10^{11}$ ohm).

A periodical modulation of the ion current, conditioned by the arbitrary rotation of the container and the velocity pressure effect, constituted a peculiarity of the registered spectra, only inherent to atmospheric constituents. This permitted the accounting of container's gas separation in the course of subsequent processing of the material. Ion peaks with the following mass numbers were registered: 1, 2, 12, 14, 16, 17, 18, 28, 29, 30, 32, 34, 36, 40 and 44, respectively identified with H_1 , H_2 , C, N_1 , O_1 , OH, H_2O , N_2 , $N^{14}N^{15}$, NO, O_2 , $O^{16}O^{18}$, Ar^{36} , Ar^{40} , CO_2 and N_2O . Besides, gases with mass numbers 9, 10, 42 were registered. The question of their identification is examined below. *Author*

RESULTS AND REASONING

Gravitational Separation and Atmosphere Temperature.

Study of the dependence on altitude of the ratio of ion currents Ar and N_2 shows, that the variation of this ratio at ascent and descent has the character of a nearly-exponential drop with the altitude increase (Fig.1). This points to the presence of gravitational separation of Ar and N_2 . The comparison of Ar and N_2 ion current ratio, corresponding to these gases' content in the near-ground layer, with the value obtained during the flight, (taking into account the mass separation factor*), shows that the gravitational separation begins at 105-110 km altitudes.

* In this case this coefficient will be different from the value $\sqrt{M(N_2)/M(Ar)} = 0.8375$ [5], since ionization of the undistorted incoming flow (selection factor 1) as well as of heavy-constituent-impooverished exit flow is equally probable. Obviously, the correction factor in this case will be $(1 + 0.837)/2 \approx 0.92$.

It must be noted, that the conclusion about the presence of separation in the night atmosphere at middle latitudes of the USSR agrees well with the results of the first two experiments [1, 2] conducted in the morning hours of the summer 1959 at the same latitudes, and also with the results of American authors [6], obtained during the soundings of the upper atmosphere by means of rockets at Fort Churchill (59° No. lat.).

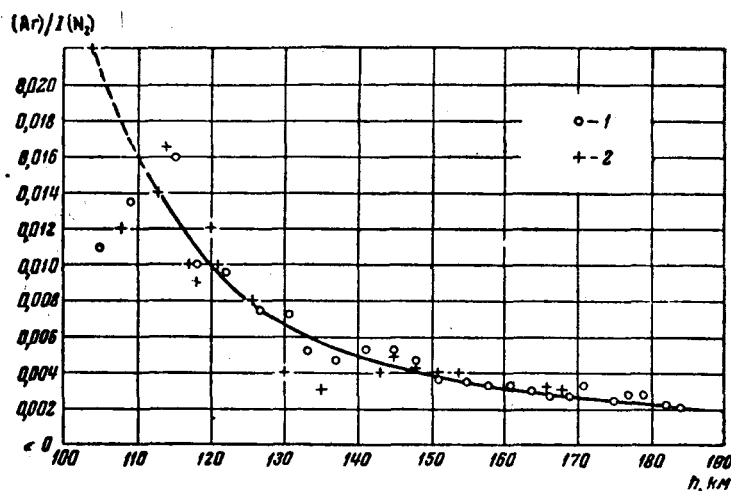


Fig. 1. Variation of Ar and N_2 ion current ratio as a function of altitude at ascent (1) and at descent (2).

But alongside with the above, there are divergences with the data obtained by the same authors during the rocket investigations of the upper atmosphere at White Sands, N.M. (32° No. Lat.). However, B. A. Mirtov [8] subjects to doubt the conclusion about the absence of gravitational separation in the atmosphere above White Sands, due to the fact that experiments were set up unsatisfactorily from the methodical standpoint. Consequently, there is a sufficient basis for the assertion that the Earth's atmosphere is in a state of gravitational separation at altitudes above 100-110 km at least at middle and near-polar latitudes. Apparently, the level of the beginning of separation cannot be strictly bounded, while

the small number of experiments prevents the reaching of the conclusion on the existence of latitude or seasonal variations of the altitude of the separation level.

As in [1, 2], the atomic nitrogen is not observed in this experiment in the 100 - 210 km altitude range in amounts exceeding 1 to 2 percent of molecular nitrogen N_2 concentration. That is why, assuming the applicability of the Dalton law to Ar and N_2 in the altitude range where the effect of photochemical reactions may be neglected (at which molecular nitrogen absorption takes place), we may estimate that the barometric formula

$$p(N_2) = p_0(N_2) \exp\left(-\frac{Mgh}{RT}\right).$$

where p , g and T respectively are the pressure, the gravitation acceleration, and the temperature at the altitude h , is valid for partial pressure variations. In this case the relative concentration of Ar with altitude will vary according to the formula

$$\frac{n(\text{Ar})}{n(N_2)} = \frac{n_0(\text{Ar})}{n_0(N_2)} \exp\left[-\frac{(M_{\text{Ar}} - M_N)gh}{RT}\right], \quad (1)$$

where $n_0(\text{Ar})$ and $n_0(N_2)$ are the absolute concentrations of Ar and N_2 at the separation level. Designating $\frac{n(\text{Ar})}{n(N_2)}$ by k , we obtain the formula

$$k = k_0 \exp\left(-\frac{h}{H}\right), \quad (2)$$

where $H = \frac{RT}{(M_{\text{Ar}} - M_N)g}$ is the altitude of the uniform atmosphere for the relative concentration of Ar. Since the ion current ratio corresponds, with the precision to the proportionality or the conversion factor, to the ratio of concentrations, we may compute the values H , and consequently — the temperature T at various heights, by applying formula (2) to the experimental curve of Ar and N_2 ion current variation with the altitude.

by the indicated method resulted possible through the 185 km altitude. The determination of the temperature above that level, indispensable for the calculation of N_2 pressure by the barometric formula, was made by way of linear extrapolation of the altitude course of the temperature curve to 210 km altitude. The result of such computations are presented in the Table hereafter. The errors of temperature determination constitute about ten percent of the measured value.

h , км	T , °K	$n(N_2)^*$ 10^{10} час- миц.см $^{-3}$	$n(O_2)^*$ 10^{10} час- миц.см $^{-3}$	$n(O_1)^*$ 10^{10} час- миц.см $^{-3}$	μ , а. е. м	p , ** 10^{-6} мм рт. см.	*** 10^{-10} г.см $^{-3}$
100	215	740	180	68	27,9	250	490
110	265	170	40	20,7	27,6	64	110
120	325	48	11	7,9	27,2	23	31
130	395	17	3,8	3,48	26,9	10	11
140	490	7,6	1,63	1,86	26,5	6,7	5,0
150	600	3,6	0,73	1,1	26,1	4,3	2,3
160	715	1,9	0,36	0,65	25,8	2,7	1,2
170	785	1,1	0,21	0,44	25,5	1,8	0,75
180	825	0,73	0,13	0,32	25,1	1,2	0,49
190	860	0,50	0,080	0,25	24,9	0,73	0,34
200	895	0,33	0,050	0,19	24,4	0,53	0,24
210	925	0,23	0,032	0,15	24,1	0,38	0,16

* particle $\cdot \text{cm}^{-3}$; ** mm. Hg.column.; *** g.cm $^{-3}$.

Basic Composition, Pressure and Density of the Atmosphere

The basic atmosphere constituents are N_2 , O_1 , and O_2 , according to experiments in the 100 — 210 km altitude range. Isotopes N_2 ($N^{14}N^{15}$) with a mass number 29 were also registered from 100 to 150 km, and in the 100 to 126 km range — isotopes O_2 ($O^{16}O^{18}$) with a mass number of 34 a.m.u. The relative concentrations of these isotopes are constant at all observed altitudes and respectively equal to $(7.6 \pm 0.6) \cdot 10^{-3}$ for N_2 and $(4.1 \pm 0.6) \cdot 10^{-3}$ for O_2 , which agrees well with the relative abundance of the isotope $N^{14}N^{15}$ ($7.6 \cdot 10^{-3}$) and of the $O^{16}O^{18}$ isotope ($4.0 \cdot 10^{-3}$) (see [9]).

Comparison was made in [4] of the experiments carried out with the aid of mass-spectrometers with different types of analyzers. As a result, the value of the corrective factor was obtained, accounting for the possible reactions that change the composition of the analyzed gases. Thus with the aid of that factor, concentration ratios of O_1 , O_2 to N_2 were obtained in the current experiment for various heights in the atmosphere.. They may serve as a basis for the

determination of absolute concentrations of atmospheric gases in the presence of corresponding laboratory calibration data on the dependence of ion currents on partial pressures. In view of the absence of data on container orientation, it was impossible to carry out the conversion of the measured partial pressures of these gases in the analyzer into their pressure in the atmosphere, taking into account the velocity of the incident flow. Fig.2 shows the curve of ion current N_2 variation with altitude at ascent. It is modulated on account of the rotation of the container by the counter flow. The curve of ion current variation at descent has an analogous character.

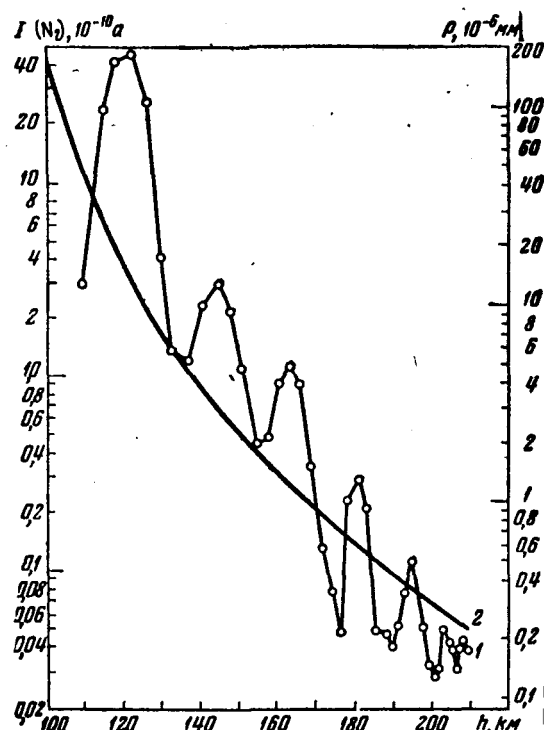


Fig.2. - (1) Ion current N_2 variation at ascent; (2) - Variation of N_2 pressure in the atmosphere per barometric formula.

It becomes possible to determine the pressure p_a in the atmosphere by the thermal effusion formula (see [10]), at the

summit of the trajectory, where the velocity of the container is near zero :

$$p_a = p_n \sqrt{\frac{T_a}{T_n}},$$

where T_n is the temperature of the device, taken as 300°K , T_a is the atmosphere temperature, and p_n is the pressure of N_2 in the analyzer, determined by the laboratory calibration curve. Having taken the value of T_a at 210 km from the Table, we obtain for the pressure of N_2 at that altitude the value $(2.2 \pm 0.4 \cdot 10^{-7} \text{ mm. Hg col})$, after deducting the background conditioned by gas separation. Applying the barometric formula, and utilizing the obtained pressure value at 210 km as p_0 in that formula, we may obtain the distribution of N_2 pressure at all altitudes where the temperature is known, and through 100 km. The obtained distribution of N_2 pressure in the atmosphere is shown in Fig. 2 (curve 2). The temperature values, necessary for the computations, were borrowed from Table for the required heights. Since intervals $h = 2.5 \text{ km}$ were used in the computations, it was then assumed that both, the atmosphere temperature and the gravity are constant quantities. Further computations making use of data [4] on relative O_1 , O_2 and N_2 concentrations permitted to obtain the distribution of absolute concentrations of the main atmospheric gases, of pressure and atmosphere density in the 100 to 210 km altitude range. The results of these computations are also compiled in the Table.

MINOR ADMIXTURES IN THE ATMOSPHERE

Group H_2O , OH , H_1 , H_2 .

In the current experiment, besides H_2 , the above-indicated gases are detected in the whole range of investigated altitudes. (see Fig. 3 next page). Contrary to the 1959 experiments [1, 2], the registered quantity of H_2O is substantially lesser, and the

character of behavior of the corresponding ion current is different. The H_2O ion current drops with the altitude, and its variation has a symmetrical character relative to the summit of the trajectory.

As may be seen from Fig. 3, the modulation of the H_2O ion current is very weakly expressed in comparison with the ion current of N_2 (Fig. 2), caused by the change in the position of the inlet opening relative to the incident flow. This points to the fact, that basically, the mass-spectrometer registers H_2O molecules, introduced in the upper layers of the atmosphere on the container's surface. Only that part of the ion current, which undergoes modulation in connection with variation of the orientation of the inlet opening of the mass-spectrometer, may be conditioned by H_2O from the upper atmosphere. However, it is not ruled out, that the modulation might be explained by the entry

into the analyzer of H_2O molecules having appeared at gas separation and which underwent reflection at mutual interaction with the molecules of the counter flow. The maximum value of the partial H_2O pressure in the upper atmosphere (at 115 km), estimated by the depth of the modulation of the ion current, does not exceed $3 \cdot 10^{-7}$ mm. Hg.col., which constitutes about 0.6 percent of the total atmosphere pressure at that altitude.

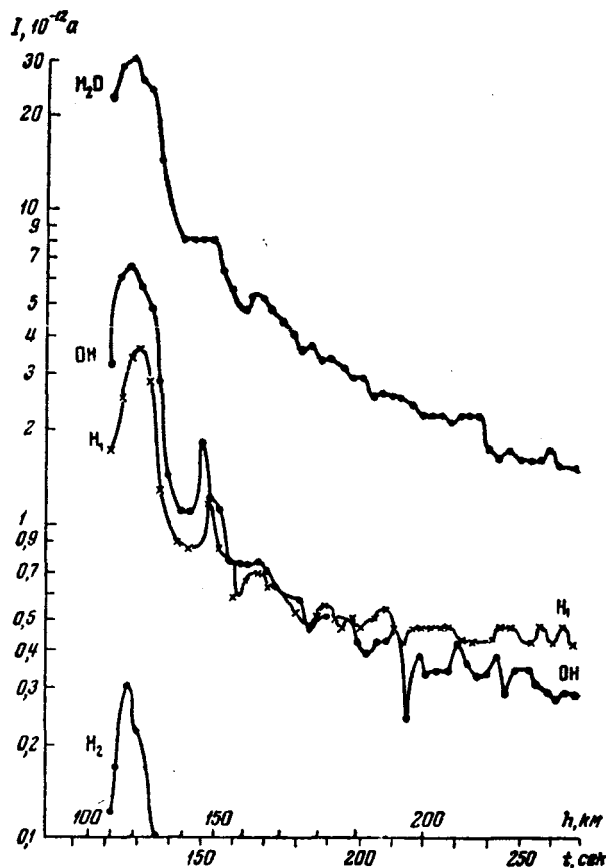


Fig. 3. Variation of ion currents of H_2O , OH , H_1 and H_2 as a function of altitude and flight time at ascent.

Taking the above considerations into account, the obtained value should be considered as the upper limit of H_2O content in the night atmosphere at altitudes above 100 km. At H_2O dissociation, hydroxyl OH and atomic hydrogen H_1 are formed in the ion source of the mass-spectrometer. They are subsequently subject to ionization, forming on the collector corresponding ion currents. At the same time, a correlation of H_2O ion currents and of products of (OH and H_1) dissociation may be obtained in the laboratory for every device.

The presence of the hydroxyl OH, registered by the mass-spectrometer, may be fully explained (with a precision to measurement errors) by H_2O dissociation in the ion source of the mass-spectrometer, when comparing the ion current ratios $I(\text{OH})/I(\text{H}_2\text{O})$ obtained in flight with those obtained in laboratory.

Having admitted the value of the measurement error for the upper limit of OH content in the atmosphere, we obtain that the relative hydroxyl OH content in the night atmosphere above 100 km does not exceed $6 \cdot 10^{-3}$ percent of the total quantity of all gases.

The behavior of the ion current of H_1 has a character comparable with that of H_2O and OH ion currents (Fig. 3) in its variation with the altitude, which may point to the dissociative link of H_1 and H_2O . However, beginning with the 145-150 km level, the H_1 ion current decreases more slowly than is necessary for ion current correlation $I(\text{H}_2\text{O}) : I(\text{OH}) : I(\text{H}_1)$, found under laboratory conditions, to be fulfilled.

If we figure the H_1 ion current in the form of the sum of two currents — equilibrated, satisfying the written correlation, and excess, it appears that at altitudes above 150 km the excess current exceeds by 1.5 to 2 times the equilibrated (balanced) one.

The concentration of H_1 , corresponding to the excess ion current, constitutes not less than 10^8 particle $\cdot cm^{-3}$. The possibility is not excluded that the presence of the excessive amount of H_1 is explained by atmosphere hydrogen; however, additional experiments will have to be conducted before any final conclusion is drawn.

The variation of the H_2 ion current, detectable at altitudes to 130 km in the ascending branch, correlates with the variation of the H_1 ion current. Hence the conclusion may be made, that the registered molecular hydrogen H_2 owes its origin to the recombination of the atomic hydrogen H_1 inside the mass-spectrometer's analyzer. The absence of H_2 in spectra at altitudes above 130 km may serve as evidence of the fact, that the concentration of H_2 in the atmosphere above the indicated level, does not exceed $3 \cdot 10^7$ particle $\cdot cm^{-3}$, which is the H_2 registration threshold for the given device.

The degree of atomic hydrogen recombination in the analyzer may be determined by the correlation of H_1 and H_2 ion currents, taking into account the light mass discrimination. It results that in the type of mass-spectrometer utilized, not more than 3 to 4 percent of atomic hydrogen H_1 is subject to recombination in the analyzer. Contrary to Istomin's assertion [11], this circumstance confirms the possibility of conducting quantitative measurements of atomic hydrogen concentration in the atmosphere with the help of mass-spectrometer of available construction.

Helium (He)

Within the limits of the device's sensitivity after opening the analyzer, no atmospheric helium was registered at either reading. This provides the basis to assert, that helium concentration above 100 km does not exceed $6 \cdot 10^7$ particle $\cdot cm^{-3}$. Comparison with the data of American authors [6] confirms the conclusion of the preferableness of studying the atmosphere composition with the help of a con-

container separating from the rocket, by comparison with measurements made by a rocket-born device. In the latter case the strong effect of gases emitted by the rocket is unavoidable. Thus, in particular, helium detected in the 130–170 km altitude range according to [6] should be entirely ascribed to gas emission by the rocket on which helium was used as an operation gas, on account of its concentration (above 10^8 particle $\cdot \text{cm}^{-3}$) and the character of the variation of this concentration with altitude. But in order to reach more precise conclusions on light gas content in the upper atmosphere that may be obtained on a separating container, additional experiments are pre-requisite, with the use of mass-spectrometers more sensitive to hydrogen and helium.

CO₂ and N₂O

Little can be said of the content in the atmosphere of gases with a mass number of 44, due to the fact that in the current experiment increased CO₂ emission by the container took place. The variation of the (CO₂ + N₂O) ion current shows a monotonic drop with altitude increase, and a feebly-modulating character due to the counter flow (similarly to the H₂O ion current). The upper boundary of CO₂ + N₂O content in the atmosphere is determined by the depth of ion current corresponding to 44 modulation, as was done for H₂O. The maximum concentration value for the mixture of these two gases at 120 km constitutes 1 percent, which about coincides with that found during the 1959 experiment [1, 2]. In this gas mixture, a certain part may consist of CO₂, forming at reactions of atomic and molecular oxygen of the atmosphere on the thorium oxide cathode of the ion source.

The gas with a mass number of 12 (carbon C) must be considered as forming at CO₂ dissociation in the ion source of the mass-spectrometer, as indicated by the independence of gases' ion current ratios with mass numbers 12 and 44 on the altitude [$I(C) : I(\text{CO}_2 + \text{N}_2\text{O}) = 0.015$].

NO.

A small quantity of gas with a mass number of 30, identified as NO was registered at ascent and descent from 130 to 180 km altitudes. The concentration of NO at these altitudes constitutes about 0.1 percent of N_2 concentration. Apparently, a substantial part of the registered NO was formed inside the analyzer as a result of charge-exchange reactions of the type $O_1^+ + N_2 = NO^+ + N$. The correlation between the variation with altitude of concentration ratios NO/N_2 and O_1/N_2 constitutes an indication to that effect. Because of that the indicated quantity may only be considered as the upper limit of NO concentration in the atmosphere at 130 to 180 km altitudes.

Gases with Mass Numbers of 9, 10 and 42.

Such noncharacteristic gases for atmosphere near-the-ground layers were registered at ascent and descent at altitudes from 100 to 125 km. The ion current ratios for two of these gases with mass numbers of 9 and 10 to N_2 are nearly similar at all altitudes in that range and respectively equal to $(5 \pm 2) \cdot 10^{-5}$ and $(4 \pm 1.5) \cdot 10^{-5}$. The ratio of concentrations of these gases to that of N_2 , taking into account the light gases' discrimination in the analyzer, will be about eight times greater than the above ion current ratios. So far, the identification of these gases has not been finally completed. A preliminary identification with beryllium Be and the bore isotope B^{10} leave open a series of questions: on the origin of these elements in the upper atmosphere, possibly cosmic (?), and on the absence of the bore's main isotope B^{11} , etc.

The detection of a gas with a mass number of 42 offers a considerable interest. This gas is registered at ascent and descent between the altitudes of 103 and 126 km. Its identification was made with the oxide of one of magnesium isotopes — Mg^{26} .

As is well known, there are three Mg isotopes with mass numbers of 24, 25, 26, the relative abundance of which is indicated by the following correlations: 78, 60 to 10, 11 to 11, 29. The relative concentration of these isotopes' oxides, whose mass numbers respectively are 40, 41 and 42, have the same correlations. The identification made does not contradict the existence of three magnesium oxides, for oxides with mass numbers of 40 and 41 could not be separated in the mass-spectrograms for the following reasons: The ion peak of the oxide of the main isotope Mg^{24} cannot be made apparent, for it coincides with the ion peak of Ar, whose amplitude exceeds that of Mg^{24}O by more than one order.

Because the DC amplifier, corrected for a higher frequency (to decrease the input RC), had a small re-correction, the Mg^{25}O peak resulted unresolved, for it coincided exactly in time with the negative "recorrection pulse" from the Ar ion peak. From the graph of Fig. 4, showing the variation of the Mg^{26}O and N_2 ion current ratios, we obtained the values of the absolute concentrations of all the Mg oxides, equal to about 10^9 part. cm^{-3} from 103 to 126 km, taking into account the relative abundance. The presence of such significant amounts of MgO in the upper atmosphere points

to its extra-terrestrial origin. Apparently, its source should be sought in meteorites, where Mg and O are the main constituents [12]: the mean weight percentage of these elements is respectively 13.9 and 34.6% of the total mass of matter. Mg is found in the meteoritic matter in the form of MgO,

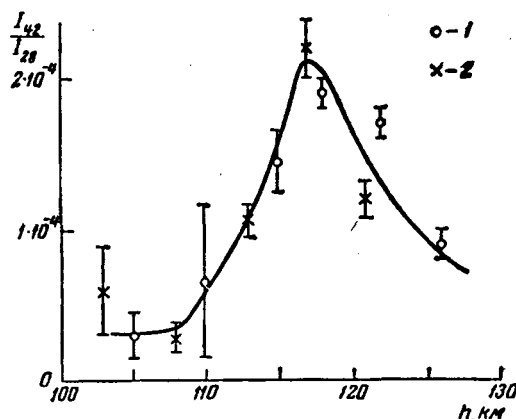


Fig. 4. Variation of the relative concentration of Mg^{26}O as a function of altitude, at ascent (1) and at descent (2).

the content of which may reach 40.2% of the total weight in stone meteorites [13], and the weight correlation between the stone and iron meteorites according to [12] is 6 to 1. These data indicate that MgO constitutes a substantial share of the meteoritic matter. In the metallic phase of meteoritic matter Mg constitutes only about 0.03% [14]. Such low content in metallic Mg, alongside with the presence above 100 km of significant amounts of atomic oxygen, with which Mg may combine, is the possible explanation of absence in mass spectrograms of ion peaks corresponding to metallic Mg.

The mutual interaction of micrometeorites constituting the bulk of meteoritic matter, with the atmosphere leads to heating and to transfer of a significant part of meteorite matter into a gaseous state. At the same time, it is obvious that the rate of vaporization of meteoritic matter will depend on the temperature of heating, which in its turn will rise with the increase of atmosphere density. Thus, the absolute concentration of gaseous matter resulting from meteorite vaporization, must increase with the density of the atmosphere, which is observed indeed if we recount the relative MgO concentrations and the absolute values brought out in Fig. 4.

As to the variations of relative MgO and N_2 concentrations it may be seen from Fig. 4, that there is a maximum at 117 — 118 km, revealed at the ascent as well as at descent. The formation of that maximum may be understood, if one starts from the concept of the existence of gravitational separation at altitudes above 100 km, and of the presence of some extended layer, transitional from the atmosphere with turbulent mixing, to the atmosphere where gas mixing has a diffusive character in regard to the laws of molecular physics. The starting gravitational separation may be partly upset in that transitional layer by separate flows from the underlying turbulent atmosphere. This entails the decrease of MgO concentra-

tion in the transition layer as a consequence of partial mixing with atmosphere layers situated below the level of meteorite total vaporization, and therefore devoid of MgO.

A conclusion may be made from the examination of the curve of the variation of Mg^{26}O and N_2 relative concentration (Fig. 4), that though gravitational separation already takes place at 105-110 km altitudes, the transitional layer reaches the 117-118 km level. Below it, the relative concentration of Mg^{26}O decreases again, but in this case it does so in agreement with the laws of Mg^{26}O and N_2 gravitational separation.

The total quantity of MgO, registered by the mass-spectrometer in the 103-126 km altitude range (assuming that it is uniformly distributed along all the Earth's atmosphere) constitutes nearly $7 \cdot 10^{11}$ g. The average amount of sporadic meteoritic matter fall on Earth for one day admitted by B. A. Mirtov [15], is $5 \cdot 10^9$ g. From the comparison of these data, one may calculate that nearly one year is required for the formation of the indicated amount of MgO.

In conclusion the author expresses his gratitude to B. A. Mirtov for his constant interest in the work and his valuable counsel, to V. G. Istomin and A. D. Danilov —for their comments on the obtained results and their constructive criticism. The author also acknowledges the active participation in the conducting of the experiment by A. A. Perno, R. F. Starostina and G. I. Podshlyayeva, and is grateful for their help in processing the material.

***** THE END *****

Entered on 7 July 1961.

References follow..

R E F E R E N C E S

1. A. A. POKHUNKOV. Izv. A.N. SSSR, ser.geofiz., 11, 1649, 1960.
2. A. A. POKHUNKOV. Sb. "ISZ" (AES), v. 7, p.89, 1961.
3. V. A. PAVLENKO, I. E. RAFAL'SON, M. E. SLUTSKIY and AL.
PTE, No. 6, 89, 1960.
4. A. A. POKHUNKOV. Sb. "ISZ" (AES), v.12, p.133, 1962 (NASA TT F-8282)
5. A. I. REPNEV. Trudy TsAO, vyp. 29, 66, 1960.
6. E. B. MEADOWS, J. W. TOWNSEND. Sp.Res. p.178, Amsterdam 1960.
7. E. B. MEADOWS, J. W. TOWNSEND. J. Geophys. Res., 61, 576, 1956.
8. B. A. MIRTOV. Gazovyy sostav atmosfery Zemli (Gas content of The Earth's atmosphere), Izd.A.N.SSSR, 1961
- 9 G. SIBORG, I PERLMAN, Dzh.KHOLLENDER. Tab.izotopov, IL, 1956.
10. B. S. DANILIN, V. V. MIKHNEVICH and AL. UFN, 63, 205, 1957.
11. V. G. ISTOMIN. Geomagn. i Aeronom. No. 3, 1961 (NASA TT F-8096)
12. B. Yu. LEVIN, S. V. KOZLOVSKAYA, A. G. STARKOVA. Meteoritika, vyp.14, 38, 1956
13. L. G. KVASHA. Ibid., v. 14, 75, 1956.
14. J. NODDACK, W. NODDACK., Naturwissenschaft, 35, 757, 1930
15. B. A. MIRTOV. Sb. "ISZ" (AES), v . 4, p.118,, 1960.

Translated by ANDRE L. BRICHANT
for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
on 7 October 1962.